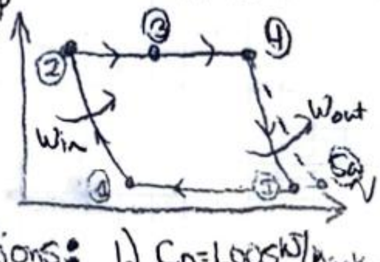
1.

Name: Brad Ethridge — Test 1 MET350 | Date | Locker/Desk No. | Course & Section No.

1.) Purpose: Using solar energy as the source of heat addition in an ideal cold air standard Brayton cycle to find the thermal efficiency & HX, mass flow rate, & Thermal eff. if HX is 100%.

Diagram:



Considerations: 1.) $C_p = 1.005\,kJ/kg\cdot K$, $C_v = 0.718\,kJ/kg\cdot K$, $k = 1.4$, $R = .287\,kJ/kg\cdot K$ behaves as ideal gas.
2.) Isentropic efficiencies of the turbine is 0.8 or 80%.
3.) Use C_p, C_v constant for the isentropic processes.

Procedure: First, calculate all states:

1 —Isentropic→ 2 —Isobaric→ 3 —Isobaric→ 4 —Isentropic→ 5 (η_T=0.8) —Isobaric→ 5a

	1	2	3	4	5	5a
K	310	491	760	1140	720	804K
KPa	100	500	500	500	100	

given in the diagram
$P_1 = 100\,kPa$
$T_1 = 310\,K$
$P_2 = 500\,kPa$
$T_3 = 760\,K$
$T_4 = 1140\,K$

Because states 2-4 are isobaric $P_2 = P_3 = P_4$ & states 6-1 are isobaric also, $P_6 = P_1$.

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \Rightarrow T_2 = 490.98\,K$

$\frac{T_5}{T_4} = \frac{P_5}{P_4}^{\frac{k-1}{k}} \Rightarrow T_5 = 720\,K$

$\eta_T = \frac{T_4 - T_{5a}}{T_4 - T_5}$

$T_{5a} = 804\,K$

Having all of the state we can solve for q_{in} & W_{net} to obtain thermal efficiency

$q_{in_{3-4}} = C_p(T_4 - T_3) \Rightarrow q_{in_{3-4}} = 381.9\,kJ/kg$

$W_{net} = W_{T_{out}} - W_{C_{in}}$

$W_{net} = C_p(T_4 - T_5) - C_p(T_2 - T_1) = \ldots$

$W_{net} = 250.25\,kJ/kg$

Calculations:

Now, having both q_{in} & W_{net} we can solve for Thermal efficiency & HX.

$\eta_{Th} = \frac{W_{net}}{q_{in}} \Rightarrow .655$ or 65.5%

for HX: $\varepsilon = \frac{T_3 - T_2}{T_{5a} - T_2} \Rightarrow \boxed{\varepsilon = 0.859 \text{ or } 85.9\%}$

For mass flow rate $\left(\frac{kg}{s}\right)$, given in the question it states with net power of 500kW: $\dot{W} = 500kW$

$$\dot{m} = \frac{\dot{W}}{w_{net}} \Rightarrow \frac{500\,kW}{250.25\frac{kJ}{kg}} \times \frac{1000\frac{kJ}{s}}{1\,kW} \Rightarrow \boxed{\dot{m} = 1998\ kg/s}$$

Now, for solving part C of the problem we assume under cold standards that HX is 100% to find Thermal efficiency.

$$\varepsilon = 1 \text{ or } 100\% \Rightarrow \varepsilon = \frac{T_3 - T_2}{T_{5s} - T_2} \Rightarrow 1 = \frac{T_3 - 491}{804 - 491} \Rightarrow T_3 = 804K$$

Using cold air assumptions: $\eta_{th_{regen}} = 1 - \left(\frac{T_1}{T_3}\right)(r_p)^{\left(\frac{k-1}{k}\right)}$

$$\boxed{\eta_{th\ regen} = 0.389 \text{ or } 38.9\%}$$

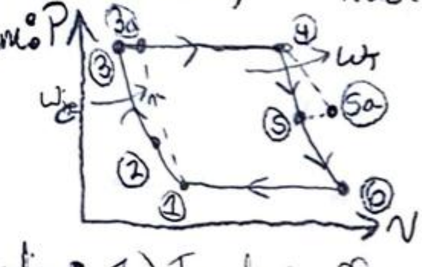
Analysis: The cold air assumption for using a heat exchanger showed a decrease in the thermal efficiency. Nonetheless, the thermal efficiency & the heat exchanger showed to be pretty effective because of the isentropic efficiency of the turbine and the quantity of net work to the heat coming in through the solar energy.

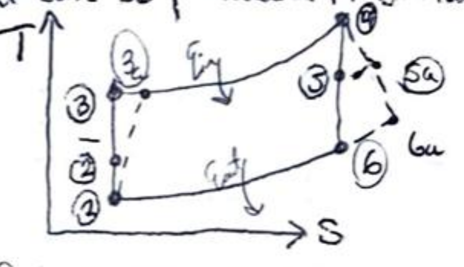
2.

Name Brad Ethridge | Lab Partner Test 1 1350 | Locker/Desk No. | Course & Section No.

2.) Purpose: Determine the pressure at turbine exit, velocity of gas exiting the nozzle, and Trust that can be produced if diffuser's diameter 1.6m

Diagram:





Considerations: 1.) Isentropic efficiencies of the compressor is 80% & turbine is 90%.
2.) Use variable specific heats for isentropic properties
3.) Ideal gas
4.) The pressures during an isobaric process are equal.
5.) The work of ~~turbine~~ turbine equals work of compressor.

Procedure: Find all states:

	1 (Isentropic →)	2 (Isentropic) $\eta_c=80\%$	3	3a (Isobaric →)	4 (Isentropic) $\eta_T=90\%$	5	5a (Isentropic)	6 (Isobaric)	6a
K	238	269	736	853	1223	725	775	403	
KPa	40	61.39	$P_3=P_4=P_{3a}$ 2626.7	2626.7	2626.7	335		$P_6=P_1$ 40	
m/s	250	0				0		804	$\boxed{865}$
P_r	.619	.950	40.647	61.17	257.47	32.87	42.33	3.92	

given:
$V_1 = 900\,\text{km/h} = 250\,\text{m/s}$
$P_1 = 40\,\text{kPa}$
$T_1 = 238.15\,\text{K}$
$T_4 = 1223.15\,\text{K}$
$\eta_c = .8$
$\eta_T = .9$

$\frac{V_1^2}{2} + h_1 = \cancel{\frac{V_2^2}{2}} + h_2$

$\frac{V_1^2}{2} = C_p(T_2 - T_1) \Rightarrow T_2 = 269\,\text{K}$

$P_{r1} @ T_1 = .619$ $\quad \frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} \Rightarrow P_2 = 61.389\,\text{kPa}$

$P_{r2} @ T_2 = .950\,\text{K}$ Interpolate

$P_{r3} @ T_3 = 40.647$

$P_{r3a} @ T_{3a} = 61.17$

$P_{r4} @ T_4 = 257.47$

$P_{r5} @ T_5 = 32.87$

$P_{r5a} @ T_{5a} = 42.33$

$T_6 @ P_{r6} = 403.285\,\text{K}$

$W_c = C_p(T_3 - T_2)$

$T_3 = 735.65\,\text{K}$

$\eta_c = \frac{T_3 - T_2}{T_{3a} - T_2} \Rightarrow T_{3a} = 852.75\,\text{K}$

$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}} \Rightarrow P_3 = 2626.65\,\text{kPa}$

$W_T = C_p(T_4 - T_5)$

$T_5 = 725\,\text{K}$

$\eta_T = \frac{T_4 - T_{5a}}{T_4 - T_5} \Rightarrow T_{5a} = 774.8\,\text{K}$

$\frac{P_5}{P_4} = \frac{P_{r5}}{P_{r4}} \Rightarrow P_5 = 335.33\,\text{kPa}$

$\frac{P_{r6}}{P_{r5}} = \frac{P_6}{P_5} = P_{r6} = 3.92$

$\frac{V_6^2}{2} + h_6 = \cancel{\frac{V_5^2}{2}} + h_5 \Rightarrow V_6 = \sqrt{2 \times C_p \times \frac{1000\,\text{m}^2/\text{s}^2}{\text{kJ/kg}}(T_5 - T_6)}$

$V_6 = 864.708\,\text{m/s}$

$W_T = 500\,\text{kJ/kg}$
$W_c = W_T$
$C_p = 1.005\,\text{kJ/kg·K}$
$C_v = 0.718\,\text{kJ/kg·K}$
$R = .287\,\text{kJ/kg·K}$
$K = 1.4$

Signature | Date | Witness/TA | Date

Calculations: I'll focus on part A and work my way down to part C.

- For part A the problem reads to find the pressure of combustion gases at turbine exit. The state at which the pressure at the turbine exit is state 5. Therefore, demonstrated by solving the states in the procedure section:

$$\boxed{P_5 = 335.33 \text{ kPa}} \quad \frac{P_5}{P_4} = \frac{P_{r5}}{P_{r4}} \Rightarrow P_5 = \frac{32.87}{257.47} \times 2626.7 \Rightarrow 335.33 \text{ kPa}$$

- For part B the question says to determine the velocity of gases at the nozzle exit. State 6 of this system locates the nozzle; So, velocity at state 6 is what the problem asks for. This is completed in the procedure section when determining all of the states.

$$\frac{\cancel{V_5^2}^{\,0}}{\cancel{2}} + h_5 = \frac{V_6^2}{2} + h_6 \Rightarrow V_6 = \sqrt{2 \times 1.005 \frac{kJ}{kg \cdot K} \times 1000 \frac{m^2/s^2}{kJ/kg} (775 - 403)\cancel{K}}$$

$$V_6^2 = h_6 - h_5 \Rightarrow C_p(T_{5a} - T_6)$$

$$V_6 = \sqrt{2 C_p \times 1000 (T_5 - T_6)}$$

$$V_6 = \sqrt{2 \times 1.005 \times 1000 (725 - 403)}$$

$$V_6 = 804 \text{ m/s}$$

$$\boxed{V_6 = 864.7 \text{ m/s}}$$

- For part C is question asks to find amount of thrust produced if diffuser inlet has a diameter of 1.6m:

$$P_1 v_1 = RT_1$$

$$v_1 = 1.70765 \frac{m^3}{kg}$$

$$F = \frac{V_1}{v_1} \times \frac{\pi}{4} D^2 (V_{6a} - V_1)$$

$$F = \frac{250 \text{ m/s}}{1.70765 \frac{m^3}{kg}} \times \frac{\pi}{4} (1.6m)^2 (864.7 - 250) \text{ m/s} = \boxed{F = 180939.3 \text{ N}}$$

$$\text{using } V_6 \Rightarrow F = \frac{250 \text{ m/s}}{1.70765 \frac{m^3}{kg}} \times \frac{\pi}{4} (1.6m)^2 (804 - 250) \frac{m}{s} \Rightarrow 163{,}072.51$$

Analysis: After computing the equation using the isentropic efficiency allowed for a higher reading by using $T_{5actual}$ resulted in 60 m/s increase, Thus increasing the overall thrust in this Jet propulsion system by roughly 10%.